II.F.5 Low-Cost, High-Pressure Hydrogen Generator (New Project)

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Objectives

Develop and demonstrate a low-cost, high-pressure water electrolyzer system

- Eliminate need for mechanical hydrogen compressor
- Increase electrolyzer hydrogen discharge pressure to 5,000 pounds per square inch gauge (psig)
- Reduce capital costs to meet DOE targets
- Demonstrate a 3,300 scfd high-pressure electrolyzer operating on a renewable energy source
- Conduct public outreach and education

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Q. Cost
- R. System Efficiency
- S. Grid Electricity Emissions
- T. Renewable Integration
- U. Electricity Costs

Approach

- Incrementally increase the operating pressure of the Giner Electrochemical Systems, LLC (GES) differential pressure electrolyzer through improved seal and end-plate design
  - 1,000 pounds per square inch differential (psid) in 2002; 2,000 psid in 2003
  - Planned further increases to 3,500 and 5,000 psid
- Replace high-cost metal components with lower-cost materials
- Innovatively replace high-cost, high-maintenance components

Accomplishments

- Reduced stack cost
  - Developed and demonstrated a low-cost cathode support

  - Reduced electrolyzer stack parts count by >50%
  - Reduction stack materials cost by 30%, fabrication labor by 40%
  - Demonstrated operation of lab-scale hardware at 10,000 amps/ft^2
- Increased operating pressure to 2,000 psid
- Developed and demonstrated operation of 140 scfd stack at 2,000 psid
- Developed, fabricated and demonstrated a system for production of 140 scfd hydrogen at 2,000 psid

Future Directions

Remainder of FY 2004

- Develop a low-cost anode support structure
  - Demonstrate and test in short stacks
- Conduct durability testing of low-cost cathode support
  - Cycle in automated test-stand at 1,000 psid
  - Demonstrate for minimum of 10,000 cycles over 2,000 hours
- Improve 2,000-psid system
  - Extend testing for approximately 500 hours

FY 2005

- Reduce cost
  - Continue reduction in stack parts count
  - Reduce stack costs by additional 35-50%
- Develop stack and system
  - Develop and demonstrate 3,500-psid electrolyzer stack and system
- Design, fabricate and demonstrate 5,000-psid short stack

Introduction

Electrolysis of water, particularly in conjunction with renewable energy sources, is a potentially cost-effective and environmentally friendly method of producing hydrogen at dispersed sites. However, current electrolyzers have a high capital cost and are inefficient. In addition, the output hydrogen pressure from current electrolyzers based on either proton exchange membranes (PEMs) or alkaline electrolytes is generally limited to 200 psi. Thus, a multi-stage mechanical compressor is required to increase the hydrogen pressure to the 5,000 psi or greater required for storage and/or dispensing to fuel cell powered automobiles. Mechanical compressors are expensive and have high maintenance requirements and poor reliability. Elimination of mechanical compressors, or at a minimum reducing the number of compression stages required, would increase the efficiency and reliability of electrolysis systems.

Giner Electrochemical Systems, LLC (GES) has developed technology for producing hydrogen directly in the electrolyzer stack at high pressure. Prior to this project, GES demonstrated a prototype electrolyzer system that produced hydrogen at 1,000 psig. The GES technology uses a high differential pressure across the PEM, so the oxygen is evolved at near-atmospheric pressure while the hydrogen is produced at high pressure. The major goal of the present DOE project is to increase the pressure of hydrogen production in the electrolyzer stack to 5,000 psi while reducing the cost of the stack and system. This will provide a cost-efficient, reliable system for generating high-pressure hydrogen.

Approach

GES has designed a focused project to increase the pressure capability of the PEM electrolyzer from 1,000 psi to 5,000 psi, decrease system costs to meet

DOE targets, and increase system electrical efficiency. The project plan consists of a sequential progression of laboratory experiments and engineering prototypes with each generation of prototype demonstrating increased pressure, improved designs or materials that are lower-cost and increased efficiency. At the end of the project, GES will demonstrate a 5,000-psi electrolyzer system.

The approach to increasing the hydrogen production pressure is to evaluate alternative materials and designs for 1) the end-plates, 2) the internal cell components that support the membrane, and 3) the cell frames that provide sealing. As part of the cost reduction effort, GES is lowering catalyst loadings significantly, as well as developing replacements for the expensive niobium and zirconium cell supports/current collectors. Another important aspect of cost reduction is decreasing the parts count per electrolyzer cell, which GES is addressing by designing single-piece components to replace multi-layer components. Improving electrolyzer electrochemical performance reduces cost by decreasing the number of cells required to produce a given quantity of hydrogen. Efficiency improvements are addressed through 1) use of thinner, less resistive membranes; 2) operating at higher temperatures; and 3) advanced catalysts. To further reduce cost, GES is evaluating advanced system concepts.

Results

GES has developed and conducted initial testing of a prototype electrolyzer stack and system that produces 140 scfd hydrogen at 2,000 psi. A photograph of this system is shown in Figure 1. The electrolyzer stack contains a single-piece, low-cost cathode support/current collector that replaces a multi-layer structure containing zirconium metal. This improved support/current collector, together with other advances in stack design, reduced 1) stack parts count by greater than 50%, 2) stack materials cost by 30%, and 3) stack assembly labor by 40%.

Contributing to the reduced stack cost was an 80% decrease in the noble metal catalyst loading. As shown in Figure 2, in single-cell testing a membrane-electrode assembly (MEA) containing a total of 1 mg/cm^2 noble metal had performance

Figure 1. Photograph of 2000-psi Electrolyzer System

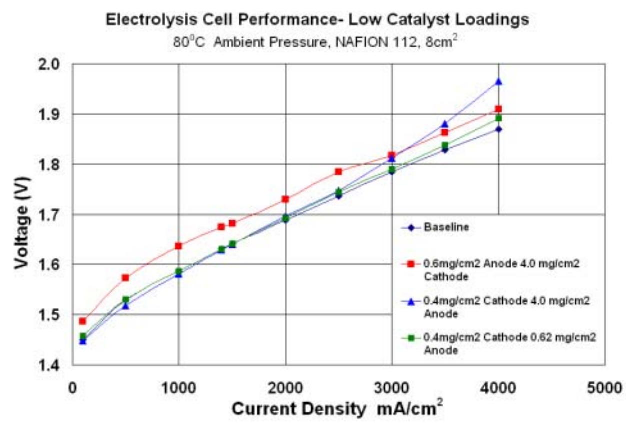

Figure 2. Effect of Catalyst Loading on Single-Cell Performance

comparable to that of a baseline MEA containing 8 mg/cm^2 noble metal (4 mg/cm^2 Pt on cathode, 4 mg/cm^2 Pt plus Ir on the anode) at current densities up to 4,000 mA/cm^2.

The improvements in stack and MEA design to reduce cost also provided improved stack performance (lower voltage), resulting in higher efficiency. Figure 3 shows that the average single-cell voltage of 1.8 V at 1,200 amps/ft^2 (ASF) at 500

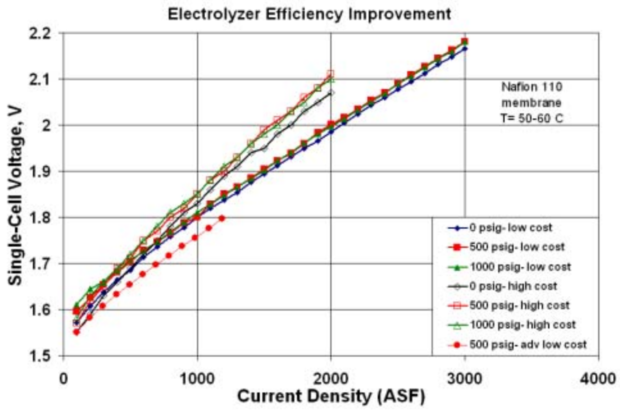

Figure 3. Electrolyzer Efficiency Improvement

psi in the advanced low-cost stack is approximately 5% lower than the 1.9 V obtained with the previous higher-cost stack design.

Conclusions

An advanced, lower-cost electrolyzer stack and system that directly produces hydrogen at 2,000 psi was developed and demonstrated. The advanced electrolyzer stack contained materials and design advances leading to improved performance as well as a significant reduction in stack cost and complexity. The 2,000-psi stack and system provides a good foundation for future development of a low-cost electrolyzer system that produces hydrogen at 5,000 psi, the ultimate goal of this project.

Future work includes design and demonstration of a stack and system for production of hydrogen at 3,500 psi, followed by 5,000 psi. The design effort will focus on advanced end-plate and seal designs. Stack cost reduction will focus on decreasing the parts count and complexity of the anode support structure/current collector. Advanced system design concepts will be evaluated and implemented in future prototypes.